

# Economic and sociocultural impacts of fisheries closures in two fishing-dependent communities following the massive 2015 U.S. West Coast harmful algal bloom

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## ABSTRACT

In the spring of 2015, a massive harmful algal bloom (HAB) of the toxin-producing diatom *Pseudo-nitzschia* occurred on the U.S. West Coast, resulting in the largest recorded outbreak of the toxin domoic acid and causing fisheries closures. Closures extended into 2016 and generated an economic shock for coastal fishing communities. This study examines the economic and sociocultural impacts of the Dungeness crab and razor clam fisheries closures on two fishing-dependent communities. Semi-structured interviews were conducted with 36 community members from two communities impacted by the event – Crescent City, California and Long Beach, Washington. Interviewees included those involved in the fishing, hospitality, and retail industries, local government officials, recreational harvesters, and others. Interviews probed aspects of resilience in economic, social, institutional, and physical domains, based on the contention that community resilience will influence the communities' ability to withstand HAB events. Dimensions of vulnerability were also explored, encompassing sensitivity of the communities to HAB events and their adaptive capacity. Common themes that emerged from the interview responses indicate that economic hardships extended beyond fishing-related operations and permeated through other sectors, particularly the hospitality industry. Significant barriers to accessing financial and employment assistance during extended fisheries closures were identified, particularly for fishers. Long-held traditions surrounding crab and shellfish harvest and consumption were disrupted, threatening the cultural identities of the affected communities. Community members expressed a desire for clearer, more thorough, and more rapid dissemination of information regarding the management of fisheries closures and the health risks associated with HAB toxins. The likelihood of intensifying HABs under climate change heightens the need for actions to increase the resilience of fishing communities to the economic and sociocultural impacts caused by HAB-related fisheries closures.

## 1. Introduction

Many coastal communities on the west coast of the U.S. remain tightly tied to fisheries resources. At least 123 communities in Washington, Oregon and California can reasonably be described as fishing communities (Norman et al., 2007). Such communities are identified in the Magnuson-Stevens Fisheries Conservation and Management Act as being “substantially dependent on or substantially engaged in the harvest or processing of fishery resources to meet social and economic needs” (U.S. Department of Commerce, 1996).

Perturbations to the fisheries that these communities rely on can reduce fishing opportunities and decrease landings, causing economic impacts, erode cultural identity, and negatively affect the physical and mental health of individuals (Hanna and Hall-Arber, 2000; Anderson et al., 2003; Clay and Olson, 2008; Martin, 2008; Olson, 2011; Colburn and Jepson, 2012; Himes-Cornell and Kasperski, 2016). These sociocultural consequences can propagate through fishing communities to impact individuals who are not directly involved in fisheries. Poor mental health, decreased life expectancy, increased poverty, alcoholism, drug use, and an overall loss of cultural identity have been documented in

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communities that suffer long-term declines in fisheries (Hanna and Hall-Arber, 2000; Martin, 2008; Olson, 2011).

Recognition of these impacts has primarily emerged from examining disruptions to fishing resulting from the collapse of fisheries, introduction of policies and management strategies to reduce fishing effort and allow stocks to recover, and social pressures to fishing communities such as gentrification. Despite evidence of harmful algal blooms (HABs) significantly disrupting important fisheries, few economic and social impact assessments of HABs have been performed and formal documentation of the sociocultural consequences is minimal (Jewett et al., 2008). Commercial fishery impacts from HABs result from harvest losses of fish and shellfish resources due to contamination with HAB toxins and farmed fish kills (Conte, 1984; Evans and Jones, 2001; Hoagland et al., 2002; Jin et al., 2008). Losses can also occur to the seafood industry due to sales volume loss from diminished consumer confidence in seafood safety (Lipton, 1998). Other societal costs of HABs include public health (human sickness and death) (Hoagland et al., 2009), recreation and tourism (Evans and Jones, 2001; Oh and Ditton, 2005; Larkin and Adams, 2007; Morgan et al., 2009; Dyson and Huppert, 2010), beach cleanup (Evans and Jones, 2001), and monitoring and management costs (Hoagland et al., 2002). At a national level, the annual economic impact of HABs in the U.S. is estimated at up to \$83 million, but this is a highly conservative estimate and the authors acknowledge that single events can occur that equal or exceed the annual average of HAB impacts for the entire nation (2000 dollars; Hoagland et al., 2002). Studies of the sociocultural impacts of HABs in coastal communities are even more limited. A snapshot of the lived realities of six local residents in Cornwall, U.K., identified a loss of sense of place and reduced opportunities for recreational and therapeutic experiences at the coast due to HABs (Willis et al., 2018). Willis et al. (2018) argue that cultural insights are needed to contextualize the ecological and economic impacts of HABs in order to arrive at locally appropriate solutions to increase the resilience of individuals and communities to future HAB events.

Without a more complete understanding of the economic and sociocultural impacts of HABs and the ability of communities to respond to them, regulating and governing agencies are challenged to focus their emergency response strategies to provide the most effective assistance. Bauer (2006) outlined a human dimensions strategy for harmful algal research and response, calling for research to (1) develop baseline and event-specific information on communities that may be directly or indirectly affected by HABs, (2) develop rapid assessment techniques for immediate deployment during HAB events, and (3) collect baseline information on institutional arrangements and regulating communities within which governmental decisions are made. Little progress on these research priorities has been made in the past decade and no standardized tools are readily available to describe the social, cultural, and economic impacts of severe HAB events.

Beginning in May 2015, a massive HAB of marine diatoms in the genus *Pseudo-nitzschia* occurred on the U.S. West Coast from California to Alaska (McCabe et al., 2016). Some species of *Pseudo-nitzschia* can produce the toxin domoic acid that can accumulate in filter feeding fish such as anchovies and sardines, and in shellfish such as crabs and bivalves. Human consumption of seafood contaminated with domoic acid can cause amnesic shellfish poisoning, a life-threatening illness characterized by gastrointestinal and neurological disorders (Perl et al., 1990; Teitelbaum, 1990). To prevent acute poisoning by domoic acid, regulatory agencies impose commercial and recreational fisheries closures when toxin levels in seafood exceed regulatory limits for human consumption. While these closures are effective at preventing illnesses, they can generate economic shocks for coastal communities that are dependent on fisheries resources (Bauer, 2006).

The 2015 HAB event resulted in numerous fisheries closures in Washington, Oregon and California that were imposed in May 2015 and continued through the winter and spring of 2016 in some regions. The commercial Dungeness crab and recreational razor clam fisheries were

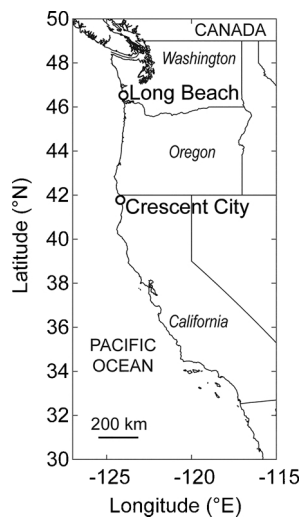
particularly impacted. The commercial Dungeness crab fishery is one of the most important fisheries on the U.S. West Coast, generating high revenues and serving as a dominant node in regional fisheries connectivity networks (Fuller et al., 2017). The 2015 HAB event caused the Dungeness crab fishery opening to be postponed by one month in Washington and Oregon and almost six months in parts of California. Compared with the previous season, the U.S. West Coast commercial Dungeness crab fishery experienced a decrease in revenue of \$97.5 million in 2015 (National Marine Fisheries Service, 2016), due in part to the fisheries closures stemming from the HAB event.

The recreational razor clam fishery is highly popular in Washington State. The razor clam season typically occurs in the winter from October through April when many other outdoor recreation activities are not in season. As many as 30,000 razor clam diggers will visit the small coastal communities on the Washington coast in a single day, and many coastal businesses depend on commerce associated with clamming activities for a significant portion of their annual income (D. Ayres, personal comm.). A season-long closure of the recreational razor clam fishery in Washington State, such as occurred in 1998–1999 and 2002–2003, is estimated to result in \$24.4 million in annual lost expenditures (2008 dollars; Dyson and Huppert, 2010). In Long Beach, Washington, 54 days of razor clam harvest, or about 40% of the 2015–2016 razor clam season, were lost due to the 2015 HAB event.

The 2015 HAB event was associated with anomalously warm waters in the northeast Pacific Ocean, informally termed the “Blob” (Bond et al., 2015; McCabe et al., 2016). Notably, all of the major *Pseudo-nitzschia* HAB events on the U.S. West Coast have occurred after periods of warming (McCabe et al., 2016; McKibben et al., 2017). Projected warming over the coming decades raises questions about the frequency and severity of future HAB events in this region, and whether or how communities will cope with potentially longer and more frequent fisheries closures. The research reported here sought to (1) identify some of the economic and sociocultural impacts experienced by two U.S. West Coast fishing communities, Crescent City, California and Long Beach, Washington, following the 2015 HAB event and (2) determine how those impacts shape community members’ perceptions of the future.

### 1.1. Selection of communities

The two focal communities, Crescent City, California and Long Beach, Washington, were selected for this study because (1) they are strongly dependent on fisheries resources and they exhibit social vulnerabilities that could influence their ability to cope with the fisheries closures (NOAA, 2016b), (2) they both have Dungeness crab and razor clam fisheries, with Dungeness crab typically the largest volume and highest value landing in their ports (Pacific Fisheries Information Network (PacFIN), 2017), and (3) they experienced closures to both the commercial Dungeness crab and recreational razor clam fisheries during the 2015 HAB event (Dan Ayres, pers. comm., 2016; McCabe et al., 2016; California Ocean Science Trust, 2016). The first criteria were assessed using the National Oceanic and Atmospheric Administration’s (NOAA’s) economic and social vulnerability index at <http://www.st.nmfs.noaa.gov/humandimensions/social-indicators/map> (NOAA, 2016b). A cross-section of NOAA representatives and others expanded upon a framework initially developed by Jepson and Colburn (2013) for the U.S. Southeast and Northeast regions to calculate these indices for coastal communities around the U.S. (NOAA, 2016a). Crescent City and Long Beach score medium to high on indicators for fishing engagement and reliance, which represent the importance of commercial fishing to the communities, and score medium to high on most indicators for community social vulnerability (i.e., labor force, housing characteristics, poverty, population composition, and personal disruption). Community social vulnerability indices represent factors that can shape the ability to adapt to change, such as fisheries harvest closures due to HABs (Jepson and Colburn, 2013). These indicators



**Fig. 1.** Map of the U.S. West Coast showing the locations of the two focal communities; Crescent City, California and Long Beach, Washington.

suggest a level of fisheries dependence and socioeconomic vulnerability in these communities that could influence their ability to respond to the economic shock generated by the fisheries closures caused by the 2015 HAB event. The main difference between the two communities is that Long Beach is a highly popular destination for recreational razor clamming, whereas Crescent City does not experience significant tourism associated with its razor clam fishery.

#### 1.1.1. Crescent City, California

Crescent City lies in Del Norte County, California (Fig. 1), just south of the Oregon/California border, and has a population of 7643 (U.S. Census Bureau, 2016). Crescent City is an isolated community, with the nearest major city (Portland, Oregon) more than 300 miles to the north. The Port of Crescent City ranks 78<sup>th</sup> in the nation for commercial fisheries value, landing 9.3 million pounds of product worth \$12.8 million in 2014 (NOAA, 2015). The port, on average, leads the state of California in Dungeness crab landings, which accounted for almost 90% of the total landings in 2014 (Pacific Fisheries Information Network (PacFIN), 2017). Crescent City is also one of the few communities in California that has razor clam beaches (National Coastal Ecosystems Team (U.S.), 1983); but, unlike Long Beach, it is not a popular razor clamming destination and tourism around the recreational razor clam fishery does not substantially contribute to the local economy.

#### 1.1.2. Long Beach, Washington

Long Beach is located in Pacific County, Washington (Fig. 1). The combined population of the small peninsular communities of Long Beach, Ilwaco, and Chinook is 4775 (U.S. Census Bureau, 2016). Constituting a single landing port (Ilwaco-Chinook), the three municipalities are treated here as a single community and are referred to collectively as Long Beach. The nearest city offering retail, grocery, and dining chains and a full-service hospital is approximately 18 miles away and the nearest major city (Portland, Oregon) is located 115 miles to the southeast. The port of Ilwaco-Chinook ranks 49<sup>th</sup> in the nation for commercial fisheries value, landing 27 million pounds of product worth \$25.2 million in 2014 (NOAA, 2015). The highest valued landings are Dungeness crab, accounting for 45% of the landed value at the port in 2014 (Pacific Fisheries Information Network (PacFIN), 2017). Long Beach is a popular recreational razor clamming destination that attracts tens of thousands of tourists from across the Pacific Northwest, annually contributing millions of dollars to the local economy (Dyson and Huppert, 2010).

## 2. Methods

### 2.1. Data collection

In-person, semi-structured interviews were conducted in the two focal communities. An interview guide (Appendix A) was developed and included slight variations for interviewees from different employment sectors and recreational harvesting habits. The interview guide probed aspects of resilience in economic, social, institutional, and physical domains based on the contention that community capital in these domains will influence the communities' ability to withstand HAB events. Dimensions of vulnerability were also explored, encompassing the sensitivity of the communities to HAB events and their adaptive capacity. The guide and study methods were approved as exempt by the University of Washington Institutional Review Board.

Quota and snowball sampling methods were utilized to recruit interviewees from seven sectors – lodging, food service, government, non-profit, recreational fishing (occupational, such as charter fishing, and non-occupational), commercial fishing, and processing. Sectors were chosen based on informal discussions with state managers in which the managers shared personal observations on which sectors of the community were most impacted by the 2015 HAB event. This was augmented by recommendations given by interviewees through snowball sampling (i.e., where interviewees identified future potential interviewees from their acquaintances). Interviewees were identified through personal connections, recommendations, and internet searching and were recruited by phone. The research team aimed to secure at least two interviewees from each sector for a target total of at least 15 interviewees from each community, which is sufficient for providing adequate insight in a non-probabilistic study of lived experience (Bernard, 2013).

At the start of each interview, permission was obtained from each interviewee to conduct the interview, a standardized overview of privacy measures was shared, and participants were offered a \$30 grocery store gift card incentive for their participation. The majority of interviews were conducted by pairs of researchers, during which one researcher asked questions from the semi-structured interview guide and the second researcher took notes and managed the voice recorder. In total, 17 interviews were conducted in Crescent City and 19 in Long Beach, with interviewees spread across the seven sectors (N = 36). Many interviewees in both communities were associated with multiple sectors, especially the recreational fishing sector, due to diversified income sources and strong fishing traditions.

Interviews were transcribed and edited for transcriber errors, crosstalk, and extraneous material. An “interviewer” and “interviewee” label system was applied to each interview to ensure the confidentiality of the participants and to avoid potential biases that could result from labels such as male, female, or recognizable names.

### 2.2. Qualitative analysis

#### 2.2.1. Development of the codebook

The Inductive (Data-Driven) Approach was followed to build the codebook (Bernard et al., 2016). The process involved reducing the raw data, identifying and comparing themes, and creating codes. Three researchers from the larger team completed this process by first individually reading through all transcripts and corresponding notes and collectively identified four exemplar interviews from each community that represented different sectors and views. These representative interviews were used in the next step of pile sorting.

For each community, the three team members separately conducted a pile sort of the four representative interviews using modified recommendations outlined by Bernard et al. (2016). From the sorting, an agreed-upon list of themes and subthemes emerged. These were colated to form the foundation of the codebook.

The codebook consisted of an organizational table comprising the codes based on the themes and subthemes that arose from the pile

sorting, and was further modified through group discussion and testing (Appendix B). The table included a hierarchy for the codes, a mnemonic system, a short and long code description, inclusion and exclusion criteria, and typical, atypical, and “close but no” examples. Individual researchers completed this table separately for the eight interviews (four representative interviews from each community). Descriptions and selected quotes were then compared and discussed amongst the team, resulting in the addition, elimination, and editing of various codes. Then, a randomly selected interview from each community (that was not one of the eight interviews used to create the codebook) was coded by the three team members to test both the rigor of the codebook and the consistency of coding between researchers. Researchers engaged in detailed discussions regarding differences in the results to refine the codebook and ensure alignment in the use of the codebook. After researcher agreement on the codebook was met, the 36 interviews were divided evenly between two researchers for coding.

### 2.2.2. Identification of themes and sub-themes

Two members of the research team individually analyzed each section of the coded transcripts to identify themes. These researchers shared individual analyses of the coded transcripts with the larger team and collaborated to create an agreed-upon list of salient themes that were present across multiple interviews.

## 3. Results and discussion

Commercial and recreational fishing activities surrounding shellfish resources are integral to both the economic and sociocultural fabric of Crescent City, California and Long Beach, Washington. The interview data provide context about the importance of shellfish to the communities and capture interviewees' experiences and perceptions surrounding the 2015 HAB event, including the economic and sociocultural impacts of the fisheries closures stemming from the toxic bloom. The primary themes that emerged from this analysis are economic impacts, sociocultural impacts, community resilience and vulnerability, and perceptions of the future.

### 3.1. Economic impacts

#### 3.1.1. Seasonality

The seasonal nature of the Dungeness crab and razor clam fisheries is an overarching factor that drives many of the activities surrounding the fisheries and hospitality sectors in both communities. The fisheries closures stemming from the 2015 HAB event coincided with peak seasons for the fisheries, magnifying the economic impacts. For workers in the fishing industry, as one interviewee explained, “you're bankrolling on your crab season being phenomenal” because the income earned from the commercial Dungeness crab fishery is a significant portion of total annual income. In the hospitality industry in Long Beach, razor clamming attracts tourists during the winter, which interviewees noted is an otherwise slow season for tourism. When clam tides open in the winter, business picks up and “it's almost like summer again... everybody's busy.” When seasonal occupations fail to produce the anticipated income, as was the case in 2015, residents are left with few options for supplemental income in part because of declining employment opportunities in other natural resource occupations such as logging and other fishing operations. The reliance on short, seasonal windows for income in these fisheries-dependent communities, combined with the lack of economic alternatives, left residents susceptible to economic hardship following the 2015 HAB event.

#### 3.1.2. Fishing industry

The fisheries closures stemming from the 2015 HAB event directly affected jobs across the fishing sector to impact fishers, processors, harbor districts, and the overall shellfish market. Many fishers reported substantial negative impacts to their finances due to the fisheries

closures. For example, one fisher recalled that the closures led to “the first time ever I've had to borrow money against my property to pay my property taxes and my fish and game licensing.”

Interviewees often commented that individuals lower in the fisheries employment hierarchy, particularly deckhands, experienced more severe impacts from the fisheries closures. Unpaid pre-season work performed in anticipation of a fishery that failed to open (and therefore failed to provide income) caused some crew members to exhaust their unemployment benefits or exhaust savings earned in previous seasons. Without an established line of credit, one interviewee said that it was not easy for younger crew members to borrow money to sustain themselves during the closures.

Harbor districts, which derive revenue from fisheries landings, experienced reduced revenues during the fisheries closures. Fish processing facilities and fish markets were also affected because they had no product to sell. Some fishers noted that even after the closures were lifted, the processors struggled to pay fishers for the shellfish that they received. Following the fisheries closures, interviewees were concerned that market prices of shellfish would be adversely affected by negative perceptions concerning seafood safety. One interviewee likened the public perceptions around shellfish to those that emerged around beef during the mad cow disease outbreak, saying that even after the shellfish were deemed safe by authorities, there was still “panic in the public.” Another boat owner recalled one community member saying that, “if it's in a shell and it's from around here, I'm not interested.” Interviewees hypothesized that these negative perceptions contributed to lower ex-vessel prices for crab, potentially increasing the difficulty of economic recovery for fishers. Risk amplification, as a result of public aversion to even safe shellfish products, has been identified as a major economic threat to the shellfish industry (Kasperson and Kasperson, 1996; Bauer et al., 2010).

#### 3.1.3. Hospitality industry

The interview data obtained from the hospitality sector (including lodging and food services) are primarily representative of the Long Beach community because, while some tourism does occur in Crescent City, fewer members of the hospitality sector there participated in interviews. Interviewees from several establishments reported that they were able to keep their personnel employed during the fisheries closures, but that they compensated by reducing employee hours or by hiring fewer staff the following season. Without clam tides, one lodge manager explained that they had to reduce their staff's hours to the “bare bones minimum”, resulting in lost income for hospitality staff. One restaurant staff member recalled being forced to rely on the food bank once per month, whereas during past winters with more clam openers, they had earned more income and could utilize subsistence clamming. Many interviewees involved in food services and lodging noted substantial reductions to their income during winter, due to decreased tourism and the consequent declines in income among residents. One Long Beach lodge manager observed “a high attrition rate on dates in clamming season that are cancelled... about eighty percent of the reservations [are cancelled]”. Not only did establishments lose room revenues, they also lost food and beverage revenues of about \$100-300 per cancellation. Many businesses had to wait until the following summer's high tourist season to recoup some of their losses.

#### 3.1.4. Pervasiveness

The fisheries closures had pervasive impacts on the business community. Multiple businesses suffered from the lack of disposable income among those employed in the fishing industry. For example, the manager of a small business in Crescent City allowed customers to “run up their bill all year long” to then be paid at the end of crab season. Some of these customers who relied on shellfish for their income were unable to pay their accumulated bills. Schools were also affected by the closures. In Crescent City, an interviewee recalled that during the 2015 fisheries closures, “the enrollment [at a private school] was way down, because commercial fishermen... couldn't afford the tuition.” The retail



sector was similarly affected. For example, in Long Beach, local grocery stores and gas stations were impacted by reductions in the number of tourists, while in Crescent City, a marine and industrial supply store was affected by the decreased demand for fisheries-related supplies.

Pervading impacts caused even those with diversified sources of income or those in two-income households to experience serious impacts. For example, one Crescent City commercial fisher recalled financial losses from rental properties because the tenants were impacted by the fisheries closures and unable to pay rent. Another interviewee who worked as a restaurant server noted that the fisheries closures “hit [their] pocketbook twice” – reducing their family’s income by approximately 75% – because the closures slowed their restaurant business substantially and their spouse’s work as a commercial fisher was stalled until crabbing opened again. One Crescent City interviewee highlighted the degree to which the pervasive impacts affected the entire community by saying, “when crab fishing’s good, we’ve got a boomin’ little economy in this place. When crab fishing’s belly up, you got a little depression up here.” Another echoed this sentiment by saying that the closures “affect[ed] everybody. It doesn’t matter if their family has a fisherman or not. If they have a local, small business around here, they’re going to get affected.”

### 3.2. Sociocultural impacts

#### 3.2.1. Cultural connections and community identity

In Long Beach, razor clams and clamming are closely associated with community identity. As one Long Beach interviewee explained, razor clams are considered “central identifiers” of the community and “a culturalism here on the peninsula... it’s something families have done for as many generations as they’ve been in the area. [It] is a tie that binds, if you will.” The interviewee noted that community visitors quickly understand the importance of razor clams because Long Beach is filled with “iconographic references to clamming,” such as statues and mail boxes shaped like clam extraction tools, which are locally referred to as clam guns. Many interviewees in Long Beach described the harvest of razor clams as an integral and indispensable social activity that spans generations and has no substitute. Several others shared important and vivid childhood memories associated with learning how to dig for razor clams at a young age, which were often followed by memories associated with years of harvesting as a family or with their own children: “It’s a huge family tradition to go out together, whether you have morning digs or evening digs, it’s a family event, it’s a way of life.”

Many Long Beach interviewees felt a void in their community during the fisheries closures stemming from the 2015 HAB event. As one interviewee put it, “the loss of our most social shell fishing experience is, quite frankly, devastating” and that there is a “sociological impact” in the community when they cannot engage in the “activities that we believe are an integral part of life.” The same interviewee explained that the closures caused ramifications for families because they must “find a different way to be communal.” Furthermore, the interviewee expressed fear of future ramifications by explaining that, “we all gather around razor clamming days or [go] crabbing together as part of an identification point for why we live here” and that they could “lose that social interaction that binds our community together.” This description exemplifies the sense of loss of identity that permeates the Long Beach community when access to this valued resource is restricted.

One Long Beach resident who works in the hospitality industry feared that tourists could abandon their razor clamming traditions entirely after repeated fisheries closures. The resident said,

My fear would be that razor clamming would be a less and less interesting activity to non-residents and it would have a long-term damaging effect on the tourism that razor clamming generates. It’s not the cultural-ism to somebody in Seattle who’s done it as a family for generations. It’s the same thing as their family probably went to church for four generations and then their generation or generation before they stopped going and they don’t miss it. I think razor

clamming is the same way. If you’re not doing it regularly, you don’t know that you miss it when you’re not doing it.

Tourism-oriented fishing communities might thus face a more protracted threat to their economies from cultural disruptions.

In Crescent City, interviewees did not explicitly note shellfish as a central part of the community’s identity; however, the stories shared by many interviewees indicated deep cultural ties to the Dungeness crab fishery. One interviewee noted that the start of the crab fishing season engenders a shift in personal behavior. For instance, interviewees recounted that, once the crab season begins, “you’ll find a bucket of crabs sitting on your front porch”, along with other stories of how sharing shellfish is interwoven with community traditions.

In both communities, shellfish resources play a meaningful role in social activities and traditions focused around consumption. For example, in Crescent City, an interviewee recalled that they “almost always had crab on Thanksgiving and Christmas” and that “crab is always the star of the show on holidays.” Similar sentiments were shared by interviewees from Long Beach. One interviewee explained that access to these resources is traditionally important for gift-giving among Pacific Northwest Native American coastal communities. The inability to continue many traditions, including holiday rituals, celebrations, and even daily activities with family and friends, disrupted many of these sociocultural institutions, threatening the identities of the two communities and compromising the emotional well-being of residents.

#### 3.2.2. Emotional well-being

While economic impacts of natural disasters are often most apparent initially, the impacts on the emotional well-being of those confronting them can be profound, long-lasting, and substantially debilitating (Shultz et al., 2013). Consistent with this observation, interviewees in both communities reported impacts to their emotional well-being due to the fisheries closures stemming from the 2015 HAB event. Some interviewees reported feeling stress and other interviewees reported evidence of stress in community members. This stress was often associated with the financial insecurity that resulted from the fisheries closures. For instance, one interviewee noted that “I think that it’s all got a huge impact and it’s stressful when you’re not sure if you’re going to be able to provide.” Another interviewee noted that fishers “were all stressed out... pulling their hair out wondering how are we going to pay the bills? How are they going to feed their kids? Guys are losing their trucks, their houses, all kinds of stuff. Yeah it was terrible. It was bad.” In Crescent City, it was clear from the interviews that waiting for the fisheries to open had an impact on the well-being of the participants from the fishing industry. For instance, one interviewee described feeling anger as a result of the delays caused by bad weather that was “exacerbated by the fact that they’d already waited so long” for the fisheries to open following the closures due to the 2015 HAB event. Another Crescent City resident, who had considered leaving the area to fish elsewhere, explained that even once the season opened, the crab remained difficult to find, and this caused emotions similar to “a death in the family.”

Several interviewees connected emotional responses to the fisheries closures to direct impacts on families in the community. For instance, one Crescent City interviewee explained that elevated stress due to the closures extended to family units, and that a “couple of them ended up in divorce.” This sentiment was echoed in Long Beach: “you can read Facebook posts from crabber’s wives [and] you can tell it’s not all good in the household.”

### 3.3. Community resilience

Interviewees described accessing and activating social capital that increased their communities’ ability to withstand the disruption caused by the fisheries closures stemming from the 2015 HAB event. Actions that communities took include holding fundraisers and food drives and continuing participation in regularly-scheduled community events.

These activities helped convert the social cohesion and support networks within these fishing communities into material assistance for families that were struggling. For example, Crescent City held successful fundraisers to assist those most affected by the closures, especially deckhands. Food banks operated by local non-profits also contributed to relief efforts. While these resources did not alleviate all of the financial burden of the fisheries closures, they helped reduce disproportionate impacts and ensure that the fishing industry did not lack vital personnel when the season resumed. Moreover, while communities were not able to continue all fishing traditions during the closures, they were persistent in carrying on those they could. For example, residents in Long Beach continued with their annual Razor Clam Festival despite the fishery closures in 2015 (that persisted into 2016). Such activities helped to reinforce the community's commitment to its traditions and helped maintain morale during difficult times, and had the added benefit of bringing in tourism revenue.

Beyond material assistance, a strong community support system has been indicated to improve mental health outcomes for individuals after a disaster (Abramson et al., 2015). Access to social resources, such as family bonding or close connections with friends and neighbors who are coping well with the situation, can encourage more positive emotional responses, problem solving, and knowledge sharing. The Resilience Activation Framework (Abramson et al., 2015) proposes strengthening social networks before disasters as a method of accelerating the activation of these resilient behaviors during and after a disaster. Increased understanding of these sociocultural dynamics can also help avoid policies that produce unforeseen consequences when enacted in fishing communities (Lyons et al., 2016). The close-knit nature of fishing communities offers significant opportunities for increasing community capacity to withstand future HAB events.

### 3.4. Community vulnerability

Factors, or sub-themes, identified from the interview data that contributed to the communities' vulnerability to the 2015 HAB event acted to increase the sensitivity of the communities to the fisheries closures and inhibit their capacity to adapt. These factors include an aging fisheries workforce, lack of fishing portfolio diversification, institutional barriers to accessing financial assistance, ineffective communication from governing and management entities, and geographic isolation of the communities. In some cases, interviewees identified resources that are necessary to reduce these vulnerabilities to future fisheries closures.

#### 3.4.1. Aging workforce

Aging of the fisheries workforce represents a significant vulnerability among fishing communities. Some interviewees feared that more frequent HAB events would exacerbate the generational shift that the fishing industry is already experiencing. One fisher stated, "I've had one guy drop dead of a heart attack, another guy had a stroke, another guy's got colon cancer, another guy's got lung cancer... everybody's over 60 years old, and they've all got one foot on a goddamn banana peel." Meanwhile, other interviewees emphasized high barriers to entry and other factors that are deterring younger generations from entering the fishing industry, which some interviewees expected would get worse. These observations are consistent with a growing body of research on the "graying of the fleet" trend in many fisheries around the world (Hamilton and Otterstad, 1998; Al-Marshudi and Kotagama, 2006; Andreatta and Parlier, 2010; West and Hovelsrud, 2010; Russell et al., 2014; Donkersloot and Carothers, 2016). A lack of new additions to the fishing workforce deprives coastal communities of new long-term residents as well as fresh ideas that could enhance the adaptive capacity of communities to reduce their vulnerability to future HAB events.

#### 3.4.2. Lack of diversification

The lack of diversification, in terms of the fisheries that fishers

participate in and depend on for the majority of their income as well as the sources of household income, represents a significant vulnerability in both communities. Dungeness crab is arguably the most important fishery on the U.S. West Coast because it generates the highest revenues and has the highest vessel participation (Fuller et al., 2017). One fisher elaborated on the impacts of the Dungeness crab closures, even if other fisheries were open: "...a lot of these boats do more than just crab, but without crab, a lot of boat owners would probably lose their boats." This is further exacerbated by the strong connections that community members have with the fishing industry. A fisher noted that fishing is "so many families' livelihoods. Single income families...their whole financial picture is based on fishing and not just the people on the boats but the people that work at the canneries and the people that work in the fish markets." Because fishing is so central to the economies of these communities, it increases the sensitivity of the communities to perturbations that restrict access to fisheries resources. Further, many workers in the fishing industry face significant challenges when seeking alternate employment, including a lack of basic computer skills, geographic isolation, and the need to perform (unpaid) gear work to prepare boats to operate when closures end. A few interviewees did not perceive their skills as being transferrable to other occupations and that they did not "know how to do anything other than fish."

#### 3.4.3. Institutional barriers

Interviewees identified institutional barriers to accessing economic resources to alleviate some of the losses caused by the 2015 HAB event. Several fishers expressed that the barriers in gaining unemployment benefits and delays in disaster relief funding were unfair after the months they went without income. Many fishers were unable to draw unemployment benefits during the fisheries closures because either they did not pay into the unemployment system, their unemployment benefits had "run out," or they could not complete the job applications required to obtain benefits because of ongoing responsibilities for gear work and maintenance on their boats in preparation for resuming fishing when the closures lifted. Fishers largely called for an unemployment system without the barriers that frequently prevent them from attaining access. Other desired resources include a hospitalities relief fund, an effective "one-stop shop" for career resources such as business and job training, and courses in financial or computer literacy. One interviewee mentioned that in the modern economy, one must "swap meaningful, high paying jobs for meaningful, high paying jobs" and that a career resources center could help facilitate that.

In February of 2016, the Governor of California requested federal disaster assistance for California's commercial Dungeness crab fishery. The Secretary of Commerce declared the disaster almost one year later in January of 2017 for the closures during the 2015–2016 season (Pritzker et al., 2017). This declaration enabled disaster relief funds to be appropriated by Congress and is indicative of the growing understanding at the federal level of the economic impacts of HABs on fishing communities. The process of appropriating relief funds, however, can be lengthy. Funds were eventually appropriated in January of 2018, almost two years after the request. Firm, reliable, and timely support by federal and state governments following devastating HAB events is needed to bolster the resilience of fishing communities.

#### 3.4.4. Ineffective communication

Ineffective communication between government entities and community members was frequently brought up by interviewees as a factor that increased their vulnerability to the 2015 HAB event. Interviewees mostly received information about the HAB event and fisheries closures from local newspapers, social media, the State's Fish and Wildlife website, or from friends, family, and coworkers. Despite the diversity of information sources, there was a lack of overall understanding of the causes of HABs and the health risks associated with consuming contaminated seafood. Several interviewees expressed frustration that news sources did not address basic questions such as whether a HAB is a

“natural, organic event or if it was something that we need to expect more” or “what these toxins are and why they’re so terrible and what are the potential impacts” on human health.

Interviewees also cited a lack of transparency and consistency of information communicated from State agencies. Community members were confused by the testing methods used to determine if seafood were safe to eat, the results of those tests, and the management decisions that those tests informed, particularly decisions about geographic closure boundaries. One interviewee added, “Sometimes when you don’t have enough information, it’s very easy for a lot of people not to trust the government...” This sentiment was shared to an extent in both communities, and distrust in government decisions about closure boundaries was especially prevalent among fishers. Both communities are in close proximity to the state of Oregon where fisheries sometimes remained open even though the same fisheries were closed to the north and south in the states of Washington and California, respectively. Interviewees were frustrated that fisheries closures sometimes followed political boundaries rather than physical ones, leading them to believe that agencies were using “arbitrary threshold[s]” of toxicity in closing fisheries. Some interviewees believed that clearer communication about these decisions could alleviate some of this distrust and minimize the spread of misinformation amongst community members.

Interviewees desired a variety of information sources to accommodate community members with varying levels of technological acumen. But most importantly, interviewees expressed a strong desire for more rapidly disseminated information, along with clearer and more specific descriptions of closure conditions (spatial extent and timing) and health risks: “Just say cause and effect. This is what happens if you eat it, so this is what’s going to happen.”

In Long Beach, where tourism is a crucial source of income for many, interviewees felt a sense of responsibility to inform visitors about the closures and dangers of domoic acid exposure since visitors may not be informed: “As a city entity, it’s important to just be in the know so we can share and educate that with the rest of the general public.” Ultimately, interviewees desired access to information that they could understand on a personal level and that they could themselves effectively communicate. Finally, some interviewees believed that a better understanding of the causes and dynamics of HABs was needed. One interviewee expressed that if scientists, agencies, and the media can “help us understand that better, then we can plan for our future better.”

#### 3.4.5. Geographic isolation

The geographic isolation of many U.S. West Coast fishing communities, including Crescent City and Long Beach, compounds the socioeconomic impacts of HABs. Crescent City was described by residents as a “drive through” community. While it is situated along Highway 101, there are not enough attractions in the community for many travelers to stop and spend money. Long Beach, located a few miles from Highway 101, was described as a “destination” community: travelers would not visit the community without a specific reason. The smaller job pools associated with these isolated locations increase the difficulty of obtaining secondary employment when fisheries are closed. One interviewee noted that “we don’t have any smoke stack industry or tech or anything,” while another interviewee shared this sentiment by highlighting the challenges that young people face. If a young person attends college elsewhere, they accrue student debt, and even if they want to return home they cannot because, as the interviewee said, “the income is not here” to pay back the loans. The geographic isolation thus further exacerbates the aging trend in the fishing workforce.

#### 3.5. Future implications

Harmful algal blooms have grown in frequency and intensity over the past 30 years and this trend is expected to continue (Van Dolah, 2000; Glibert et al., 2005; Jewett et al., 2008; Jacobs et al., 2015), increasing the likelihood of repeated exposure to HABs in fisheries-dependent

coastal communities (Moore et al., 2008). Interviewees inside and outside the fishing industry identified the loss of homes, boats, jobs, and the inability to pay monthly bills as likely outcomes if fisheries closures due to HABs became more common. Several interviewees anticipated that they would feel the same negative emotions as they did during the 2015 closures. Some interviewees, however, feared that future events could cause a much more severe response, coming in the form of a complete cultural shift away from fishing – both commercial and recreational. A comprehensive management system for responding to future HAB events does not yet exist in either community. Disaster risk reduction strategies and emergency response plans would likely be required to coordinate the level of response necessary to mitigate the potential impacts of HABs in the future.

With the threat of increasing HABs, a number of interviewees mentioned that they had either thought about or were actively pursuing alternative marketing strategies for their communities. Interviewees in Long Beach proposed attractions that could be promoted by the tourism industry including sandcastle competitions, “storm watching” specials at local hotels and lodges, and bird-watching in nearby Willapa Bay, which was described as a “dynamic part of the Pacific Flyway.” One interviewee added that “there are a lot of hikes and educational stuff that we can do from a more ecotourism or eco-touristic perspective. That’s what we’re looking at... how we evolve into much more of an ecotourism destination” instead of just a “go-karts and fireworks destination.” Alternative marketing strategies were less commonly proposed in Crescent City where tourism plays a less important role in the economy; however, one interviewee mentioned that the city should be marketing their newly constructed harbor to sport fishers. Still, most work on alternative marketing strategies in Long Beach and Crescent City has been confined to the individual level. Broadening these efforts to a community-wide basis is an actionable approach that the communities could pursue in the present, without relying on much external aid. Creative and coordinated strategies such as these could increase the resilience of both communities, allowing them to adapt to unexpected disruptions and maintain the communities’ cultural identities.

#### 4. Conclusions

In Crescent City, California and Long Beach, Washington, economic and sociocultural impacts of fisheries closures stemming from the 2015 HAB event extended far beyond decreased fisheries landings. The economic hardships in all fishing-related operations, including fishing, processing, and fish markets, were acute, and the shock propagated throughout the communities with substantial negative effects on the hospitality, retail, and tourism sectors. At the same time, existing sources of financial and employment assistance were insufficient to counteract the magnitude and duration of the economic disruption, particularly for commercial fishers. The cultural identities of these communities were also threatened through disruptions to long-held traditions surrounding crab and shellfish harvest and consumption. While communities rallied to convert social capital into material support for those most impacted by the fisheries closures, the geographic isolation of these communities, poor rapport with management agencies, and prevailing social, economic, and demographic trends all increased their vulnerability to the 2015 HAB event.

Unlike other studies of the economic impacts of HABs, this study focused on the lived realities of individuals in fishing-dependent communities. Instead of estimating the total economic costs of the fisheries closures as other studies have done, this study uncovered pathways for how losses associated with sharply reduced landings and tourism permeated through two fishing dependent communities to impact other employment sectors. This study also identified resources that community members accessed (or desired to access) to help cope with the impacts, and barriers that prevented access to needed resources. Understanding these pathways, and the sociocultural context for them, can help guide the development of more accurate economic and social impact assessments of HABs as well as the development of policies to

minimize losses from future HAB events.

This study is not without limitations. Interview data were collected at only one time-point in each community, limiting the ability to understand how impacts change over time and how long it takes communities to recover from those impacts. Moreover, the two focal communities were selected because, among other criteria, they experienced some of the longest fisheries closures associated with the 2015 HAB event, and they exhibited social vulnerabilities that could influence their ability to cope with the fisheries closures. Results reflect the impacts to these two communities and are not generalizable across other coastal fishing communities. Future studies could investigate economic and socio-cultural impacts of fisheries closures more broadly across communities, including less vulnerable communities and tribal communities. Such an approach would enable a comparison of responses and community needs that could identify the most practical and cost-effective means of building resilience to future HAB events in the U.S. West Coast region.

Coastal communities may be exposed to HABs of increasing frequency and severity associated with climate change. Consequently, understanding the societal impacts associated with HABs is critical to developing a cohesive, long-term strategy for protecting coastal communities. Several interviewees emphasized the importance of preparing for the future and were already considering a variety of strategies to increase their communities' resilience to future HABs and fisheries closures. A robust strategy for mitigating the impacts of HABs on coastal communities will require assistance from all levels of governance and, importantly, will require significant improvements to the way that information is shared and conveyed. Accessible, transparent and effective communication of management decisions to community members that clearly explains the context and rationale behind such decisions is needed. Significant effort will need to be invested to overcome the distrust of government agencies that was expressed by interviewees.

Utilizing interview data enables voices to be heard, especially from

groups that are underrepresented in management and decision-making processes, and allows researchers and managers to uncover sentiments that may have been previously unknown. While it does add an additional consideration to management decisions, neglecting the perceptions and experiences of community members can lead to policies that misalign with the needs and ways of life in these communities. Ultimately, documenting impacts from major HAB events, such as occurred on the U.S. West Coast in 2015, can foster a greater understanding of challenges faced by coastal communities and can encourage the necessary large-scale collaboration to address these problems. Improved communication and collaboration between communities, researchers and managers involved in or affected by HABs is key to building resilient coastal communities in the face of changing environmental conditions. This type of qualitative research combined with health risk research and education efforts may help minimize public exposure to contaminated shellfish while mitigating economic and social shocks to fishing communities.

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### Appendix A. Semi-structured interview guide

Core questions from the semi-structured interview guide. Sector specific prompts for fisheries- and hospitality/tourism-related employment types are summarized.

- 1 Where do you live?
  - 2 How many years have you lived in (name of town/community)?
  - 3 What is your occupation? *Fisheries specific prompts include questions related to the type of fisheries they participate in, whether they work on a boat or shore side at a fish processing facility, how much of their annual income is related to the Dungeness crab fishery and other sources of income. Hospitality/tourism specific prompts include questions related to how much of their business depends on the Dungeness crab or razor clam fisheries.*
  - 4 Do you or any close friend or family members harvest shellfish (clams, crab, etc.), either currently or in the past? *If yes, prompts include questions related to harvest amounts, whether the harvested shellfish form a large part of their diet, traditions associated with harvesting or consuming shellfish, and concerns about the safety of harvested shellfish.*
- “In the following questions, I’ll be asking you about the 2015 harmful algal bloom. Harmful algal blooms occur when colonies of algae—organisms that live in the sea and freshwater—grow out of control while producing toxic or harmful effects on people, fish, shellfish, marine mammals, and birds. The human illnesses caused by HABs, though rare, can be debilitating or even fatal.”
- 5 Can you share what you know about the 2015 HAB event?
  - 6 As a result of the HAB event, there were extensive closures to razor clam and Dungeness crab harvests. Did you hear about these closures? *If yes, prompts include questions related to where they heard about the closures, knowledge of health risks associated with eating contaminated shellfish, whether the closures affected them and/or their business/place of employment (including revenue and staffing), and whether their business/place of employment had recovered from the impacts.*
  - 7 Did the closures have any impact on your cultural traditions, such as traditional holiday meal plans?
  - 8 Some people reported a negative impact to their physical or mental well-being following events such as the HAB closure, such as increased stress and anxiety or depression (not related to ingesting toxic shellfish). Did you, or anyone you know experience this, and if so, what was it like for them?
  - 9 Did these closures impact your community, and if so, how?
  - 10 In thinking about your overall experience with during the 2015 event, what aspects made it easier to deal with, like access to resources or community support?
  - 11 What things made it more difficult to deal with?
  - 12 How would another future HAB event with harvest closures, like 2015, impact you?
  - 13 What community/government support services do you think are needed for (enter occupation) during prolonged closures?
  - 14 Is there anything else you would like to add about the 2015 HAB event, or do you think we missed any important issue with our questions?



**Appendix B. The following is the hierarchy of codes, short code description, and long code description used for the analysis of the transcripts from Long Beach, WA and Crescent City, CA**

Hierarchy	Short Description	Long Description
Cultural Connection	Cultural connection associated with crabbing/clamming	Interviewee mentions a family history crabbing and clamming. This will often be shared as a childhood memory. This includes descriptions of clamming and crabbing; Interviewee explains that they have harvested clams/crabs in the past
Occupation & Economic Factors	Other financial resources (savings account, investments, second fishery) outside of secondary employment Personal barrier to secondary employment (such as being computer illiterate) Community economic factors (remoteness, poverty, seasonality, etc.)	Interviewee share access to additional financial resources such as savings accounts, investments, property.  Interviewee shares a barrier to secondary employment. These are personal barriers such as a skills or education. Interviewee mentions economic factors, such as remoteness, poverty, a community dependency on clam tides/crabbing season, and seasonality that impact their community.
Traditions/Family	Personal economic dependency on clam tides and/or crabbing season Tradition and Family related impacts	Interviewee expresses a personal economic dependence on crab/clams. Loss of income as a result of closures impacts traditions, less fish or crab for traditions, from fisheries closures impacts ability to carry out traditions
Mind/body Impacts	Mental Health  Physical Health	Interviewee expresses impacts to their personal or community mental well-being due to consuming contaminated shellfish or from the fisheries closures and their related impacts Interviewee mentions impacts to their physical due to consuming contaminated shellfish or from the fisheries closures and their related impacts
Employment/Industry Impact	Community economic impact (incl. cascading impacts)  Fisheries-incl. processors, canneries (must be HAB specific) Lodging impact-can include a hotel with restaurant (must be HAB specific) Food service impact-does not include a connected hotel (stand-alone restaurant) (must be HAB specific) Retail impact (must be HAB specific)  Other impact (school, hospital, non-profit) (must be HAB specific)	The interviewee expresses that there are other factors contributing to economic lost (less money in the community, less jobs, less tourism) Impacts from fisheries closures on businesses related to gathering, processing, or selling shellfish Impacts on hotels and other lodging businesses due to fewer customers during fisheries closures Economic impacts on restaurants due to fewer customers during fisheries closures Economic impacts on retail businesses due to fewer customers during fisheries closures Economic impacts on other businesses due to fisheries closures
Future Impact	Future economic impacts  Future impact to the individual and society/culture  Believes in community's/individual's ability to make it through future HAB events Does not believe in community's/individuals ability to make it through future HAB event	Economic impacts to the individuals or the community that the interviewee indicates may occur if similar fisheries closures happen again Non-economic impacts to individuals or the community that the interviewee anticipates may occur if similar fisheries closures happen again. Expresses statement of ability to adapt to future HAB events, on individual and/or community level Expresses statement of an inability to adapt to future HAB events, on individual and/or community level
Actual Resources	Pre-existing support  Responsive support  Access to HAB information	Resources within the community prior to the HAB event (WIC, food bank, businesses, government aid) Resources within the community in response to the HAB events and fisheries closures (community dinners, fishermen's wives clubs, businesses, government) The interviewee indicates how they or others learn about HABs and/or fisheries closures.
Perception of Resources	Negative qualities of the resources as in support or aid (ex. communication) - can just state a negative quality or state a problem	The interviewee expresses a negative opinion about some aspect of the support/aid they, others, or the community received, either in the amount of aid or the quality of the aid.

	Positive qualities of the resources	The interviewee expresses a positive opinion about some aspect of the aid they, others, or the community received, either in the amount of aid or the quality of the aid.
Desired Resources	Expresses desire for changes to communication of results/health risks/closures	The interviewee expresses a desire for changes to the information they receive about HABs, their health risks, and other environmental issues. This can mean more information, clearer information for non-scientists, or better communication about where to receive information.
	Expresses desire for financial support (ex. unemployment support, disaster relief grant)	If a similar HAB event were to impact the community again, the interviewee mentions this as a financial resource they would like to have. This can also be something that they expressed they had been given during the first HAB event.
	Expresses desire for non-commodity support (such as community closeness, job training)	The interviewee indicates that they wished they had these non-commodity resources during the HAB event and subsequent closures, or that they would like to have these resources available if a similar event were to happen again. Clearly expresses 'needs' or 'wants'
	Expresses need for alternative community strategies in the future (ex. building sandcastles, Pacific flyway, etc.)	The interviewee indicates that they think the community needs to develop marketing strategies or other tourism draws to help the community be more successful during fisheries closures.

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